

Article

Transforming Innovation Systems into Innovation Ecosystems: The Role of Public Policy

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Abstract: This study investigated the role of public policy in transforming innovation systems into innovation ecosystems. Despite the numerous studies that examined the role of innovation policies in promoting innovation systems and the increasing attention paid to the transition from innovation systems to innovation ecosystems in the literature, research on the role of public policy in facilitating this transition is sparse. To develop an analytical framework that identifies factors to be considered in policies that facilitate the transition towards innovation ecosystems, we synthesised the literature that investigated (1) the role of policy in innovation systems, (2) new features of innovation ecosystems and (3) the relations between (transformative) policies and innovation ecosystems. To identify these factors, we also drew on the concept of policy layering and the neo-Triple Helix model of innovation ecosystems. Specifically, we identified the following factors: the willingness and capacity of innovation actors to develop cross-boundary interactions on a global scale; an institutionalised civil society based on bottom-up media; and the prevailing sustainability ethos in economic, social and environmental dimensions. These can be used to design and evaluate policies that promote sustainable innovation and development as core features of innovation ecosystems.

Keywords: innovation policy; transformative policy; policy layering; sustainable innovation; sustainable development goals; helix innovation models; neo-Triple Helix



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1. Introduction

This conceptual study aimed to develop an analytical framework for understanding the key factors that need to be considered when designing and evaluating public policies that aim to transform innovation systems into innovation ecosystems. There are two core concepts in this purpose statement: public policy and innovation ecosystems. Public policy can be understood as ‘anything a government chooses to do or not to do’ (p. 2) [1]. Naturally, one may expect that a definition of innovation ecosystems is also provided here to better understand our research. There is no shortage of definitions of innovation ecosystems in the literature. For instance, Cai et al. [2] defined innovation ecosystems as

co-innovation networks, in which actors from organizations concerned with the functions of knowledge production, wealth creation and norm control interact with each other in forming co-evolution and interdependent relations (both direct or indirect) in cross-geographical contexts, and, through which new ideas and approaches from various internal and external sources are integrated into a platform to generate shared values for the sustainable transformation of the society (p. 2).

However, we considered the lack of an agreed-upon definition of innovation ecosystems, especially regarding how they differ from innovation systems, to be a problem, as explained below. The concept of innovation ecosystems also overlaps with notions such as business ecosystems and platform ecosystems [3]. Therefore, part of our research objective was to provide a comprehensive description of the differences between innovation

systems and innovation ecosystems, in addition to elucidating the role of public policy in transforming the former into the latter.

In recent years, the concept of innovation ecosystems has become prominent in research on innovation and sustainability [4], along with a rising consensus on promoting sustainable innovation and a shift towards ‘a renewed human-centred/human-centric industrial paradigm’ [5]. Public policy has simultaneously become oriented towards promoting innovation ecosystems and addressing related challenges [6]. Governments’ commitments to developing innovation ecosystems were also reinforced by the United Nations’ 2030 Agenda adopted in 2015, which aims to achieve the 17 Sustainable Development Goals (SDGs). Several studies (e.g., [7–9]), examined the relationship between policies and innovation ecosystems. Gifford et al. [9] understood policymaking in knowledge-intensive innovation ecosystems as an evolutionary process in which top-down exploration of policy alternatives and bottom-up knowledge-intensive entrepreneurial activity co-evolve and influence each other. Vlasisavljevic et al. [8] found that policies’ effects on the development of open innovation ecosystems depend on regional histories and contexts. Although they did not explicitly use the term innovation ecosystems, Schot and Steinmueller [7] proposed three policy frameworks for understanding the transitions from research and development (R&D) policies to innovation system policies and, in turn, to transformative innovation policies. The transformative innovation policy frame directly addresses policy changes that integrate sustainability transitions into innovation systems, thus fostering innovation ecosystems.

However, the aforementioned studies had two shortcomings. First, there was a lack of agreement on what to focus on when understanding innovation ecosystems. When exploring how policies influence the systems, the authors referred to different aspects of innovation ecosystems, such as entrepreneurship, open innovation and sustainability transitions. Second, they did not develop a systematic framework for analysing the role of policy in developing innovation ecosystems. Although some studies explicitly investigated how policies influence innovation ecosystems (e.g., [8,10,11]), the innovation ecosystems discussed in these studies were not much different from innovation systems. To rectify this, studies on the relationship between policy and innovation ecosystems should be integrated with insights from the literature on (1) the features of innovation ecosystems that distinguish them from innovation systems and (2) the role of policy in encouraging the development of innovation systems.

Several studies recently discussed what distinguishes innovation ecosystems from innovation systems (e.g., [12–15]) but they applied different comparative lenses. In their systematic literature review, Gomes et al. [16] found that ‘scholars presented different conceptualisations of innovation ecosystem, which may lead to contradictory and competing concepts’ (p. 45). By integrating these studies’ insights through an appropriate lens, one can gain a comprehensive understanding of what constitutes an innovation ecosystem.

When it comes to the role of policies in fostering innovation ecosystems, the approaches to system failure [17,18], the Triple Helix model [19,20], policy learning [21] and policy mix [22] are considered to be the most helpful [23]. Based on a review and integration of the literature on these approaches, Cai et al. [23] proposed a framework for analysing the role of innovation policy in developing innovation systems. Two assumptions underlie their framework: (1) an ideal model of innovation systems is enabled by certain conditions and (2) the role of policy is to influence local conditions to match ideal enablers. Thus, the key to constructing such a framework is to identify the conditions (both tangible and intangible) that enable innovation systems.

Cai et al.’s [23] study aimed to bridge a research gap: ‘While there are high expectations that innovation policy would foster regional innovation, it has been less understood how innovation policy actually promotes innovation processes’ (p. 239). Five years later, such a research gap has re-emerged in the context of innovation ecosystems, in line with the two aforementioned shortcomings in the literature. Beaudry et al. [6] also noted that how policy impacts innovation ecosystems is still an under-researched subject. They called for

further research to ‘understand the organisational structures of innovation ecosystems and how these are managed to accelerate and improve the innovation process and lead to better economic development and wealth creation’ (p. 539). When explaining why conducting policy analyses in the innovation system context is challenging, Cai et al. [23] pointed out three reasons: (1) the innovation system is too complex to be grasped, (2) the impacts of policy are difficult to measure and (3) existing approaches have not taken full account of the essential factors in policymaking [23]. These can also be valid when accounting for the research gaps in policy analysis within the context of innovation ecosystems, as identified in the present study: (1) there is a lack of agreement on what to focus on when understanding innovation ecosystems and (2) there are few systematic frameworks for analysing the role of policy in developing innovation ecosystems.

To address the aforementioned gaps in the literature, we posed the following two research questions:

- What unique characteristics distinguish innovation ecosystems from innovation systems?
- What key factors should be considered when designing policies to facilitate the transition from innovation systems to innovation ecosystems?

The remainder of this paper is structured as follows: in Section 2, we introduce our research method; in Sections 3 and 4, we answer the two research questions; and in Section 5, we elaborate on our paper’s scholarly significance and policy implications.

2. Research Method

To write this conceptual paper, we conducted research mainly for the purpose of theory building. According to Jaakkola [24], the challenges researchers face in writing conceptual papers are due to a lack of methodological guidance. Thus, she provided helpful suggestions on research designs for writing conceptual papers. While empirical studies draw on data based on people’s experiences, the data for conceptual papers come from the literature, typically ‘in the form of previously developed concepts and theories’ (p. 19) [24]. In this regard, a conceptual paper is similar to a literature review paper. However, a literature review is just a tool used to write a conceptual paper, not its ultimate goal [24]. Jaakkola identifies two often interrelated goals of conceptual papers: (1) to conceptualise a focal phenomenon that is observable but not adequately addressed in the existing research and (2) to improve a particular concept, theory or research domain that is incomplete in some important respects. Among the approaches suggested by Jaakkola to achieve these goals, our research employed the theory synthesis and theory adaptation approaches [24].

The theory synthesis approach integrates multiple theoretical perspectives to conceptualise a new phenomenon [24]. Such an approach is suitable for answering our first research question, which concerns the unique characteristics that distinguish innovation ecosystems from innovation systems. Despite the wide array of studies describing innovation ecosystems, their discussions are too fragmented and lack consensus on the definitions, core characteristics and theoretical roots of the systems [25,26]. To consolidate our understanding of innovation ecosystems, the current discussions on the topic need to be synthesised and integrated. Specifically, we synthesised the following literature: (1) studies that directly compared innovation systems and innovation ecosystems [12,13,25–27] and (2) studies that enhanced our conceptual or theoretical understanding of innovation ecosystems [16,28–30]. We further analysed insights from these studies using the comparative lens developed by Edquist [31] and identified the unique characteristics of innovation ecosystems from the perspective of the neo-Triple Helix model of innovation ecosystems proposed by Cai [30].

The theory adaptation approach is about ‘changing the scope or perspective of an existing theory by informing it with other theories or perspectives’ (p. 22) [24]. One example of its application is expanding an existing theory or concept by introducing a new theoretical lens [24]. Such an approach is useful for answering our second research question, which concerns the conceptualisation of the role of policy in transforming innovation systems into innovation ecosystems. We used the concept of policy layering as a theoretical lens to

expand Cai et al.'s [23] policy analysis framework regarding the role of policy in developing innovation systems. We also drew insights from studies that investigated the relations between policies and innovation ecosystems [6,9,32–34] and the literature on transformative innovation policies [35–38] that are closely related to innovation ecosystem development, especially sustainability transitions.

Policy layering is a concept that was created to better understand institutional change. It refers to 'the layering of new arrangements on top of pre-existing structures intended to serve different purposes' (p. 15) [39]. Mahoney and Thelen [40] posited that 'layering occurs when new rules are attached to existing ones, thereby changing the ways in which the original rules structure behaviour' (p. 16). In policy studies, policy layering is one of the four approaches of policy mixes for policy reforms; the other three are policy drift, policy conversion and policy integration [41]. The four approaches can be distinguished according to their coherence/consistency with existing policy goals and policy instruments (Table 1). While policy goals reflect desired outcomes, policy instruments 'are techniques of governance which, one way or another, involve the utilization of state resources, or their conscious limitation, in order to achieve policy goals' (p. 2) [41]. Since the transition from innovation systems to innovation ecosystems entails a paradigm change (which is discussed in Section 3), it requires that policymakers reorient their policy goals and instruments, which is reflected in the policy-laying approach and can be seen in the current innovation policies of the European Union (EU) [42] and EU member states (e.g., [43]).

Table 1. Typology of policy mixes according to their relations with existing policies. Source: adapted from Howlett and Rayner [41].

		Relations with Existing Policy Instruments	
		Consistency	Inconsistency
Relations with existing policy goals	Coherence	Integration	Drift
	Incoherence	Conversion	Layering

In our search and identification of relevant literature for both theory synthesis and theory adaptation, we combined traditional and systematic techniques [44]. A traditional literature review is 'often based on a personal selection of materials because the writer believes the original authors have some important contribution to make to current knowledge' (p. 15) [44]. A systematic review requires more rigorous procedures for selecting relevant literature [45]. We primarily applied the traditional approach because one of the authors has closely followed the development in the literature of related topics throughout his previous research experience and ongoing research projects. Nevertheless, we acknowledged our limitations in following the explosive growth of academic publications. Thus, we also searched for relevant articles from the Web of Science by using keywords such as 'innovation', 'ecosystem' and 'policy' in different combinations, as well as combinations of 'transformative policy', 'sustainable development' and 'ecosystem' in January 2022.

3. The Unique Features That Distinguish Innovation Ecosystems from Innovation Systems

In this section, we compare innovation systems and innovation ecosystems by synthesising the studies comparing the two systems using the consistent comparative lens developed by Edquist [31]. Then, we identify the main characteristics of innovation ecosystems using the neo-Triple Helix model [30] to pave the way for our next step of theory adaptation, which is presented in Section 4.

3.1. Innovation Ecosystems Versus Innovation Systems

While innovation ecosystems share some essential characteristics with innovation systems, they also have unique features [26]. For instance, Cai et al. [46] argued that 'what is new in the innovation ecosystem is its ecological aspect, characterised by the interdependency among different collaborative actors and the co-evolution/co-creation

that binds them together over time, along with the sustainable development dimension' (p. 6). According to Smorodinskaya et al. [15], 'Eco' 'emphasize[s] the non-linear nature of innovation and the crucial role of collaboration in producing innovations to achieve sustainable development in non-linear environments' (p. 5248). The unique characteristics of innovation ecosystems can be best understood when they are compared with those of innovation systems. Table 2 summarises the findings of some recent publications that provide the most comprehensive comparisons of innovation systems and innovation ecosystems.

Table 2. Summary of studies comparing innovation systems and innovation ecosystems. Source: authors' synthesis of the literature.

Studies and the Focus of Comparison	Dimensions for Comparison	Major Differences Identified	
		Innovation Systems	Innovation Ecosystems
Bassis and Armellini [12]: comparing the theories of innovation systems and innovation ecosystems	Concept	Originated as a system approach	Originated as an analogy and followed by efforts to theorise about the concept
	Disciplinary basis	Mainly developed by economics scholars	Mainly developed by management studies scholars
	System boundary	National, regional and sectoral	Global
	Collaborative actors	From the public and private sectors	Broad networks
	Industry's role	Industry-focused	The concept of industry is outdated
	Unit of analysis	Technological and economic performance	Opportunity environment platforms
Russo-Spena et al. [13]: comparing key components in innovation systems and innovation ecosystems to enhance the conceptual understanding of these systems	Innovation	Innovation goes beyond technical and stand-alone processes in the interpretation of single companies and instead involves shifts in technological trajectories, economic growth and development	Innovation is understood as resulting from relationships developed under the influence of the interplay of economic, social and political actors
	Context	Bounded in a geographical space or a specific industry	Networks of interdependent actors across geographical and industry boundaries
	Actors	Actors from industries, governments and universities form the main networks	The complexity of both central and peripheral actors in networks that connect and interact with other networks in both local and geographical contexts
	Enablers	Institutional context that encourages learning and innovation	Constant and balanced fertilisation of ideas, knowledge and technology between different communities and networks
	Governance	Public authorities are moderators of innovation systems, whereas interaction and coordinating mechanisms between system components are considered to be unplanned and unintentional	Both central and peripheral actors collaboratively share the structure of innovation ecosystems that forge and expand links between partners

Table 2. Cont.

Studies and the Focus of Comparison	Dimensions for Comparison	Major Differences Identified	
		Innovation Systems	Innovation Ecosystems
Amitrano et al. [14]: comparing the main topics under investigation in the innovation system and innovation ecosystem literature	Aim	To improve the entire context	To disrupt previous technologies
	Context	A geographical area	Industries across geographical contexts
	Mechanisms of innovation	Technology transfer	New relationships between different actors
	Policymakers	Steer the innovation process with a top-down approach	Support entrepreneurship and stakeholder involvement
Smorodinskaya et al. [15]: comparing innovation systems and innovation ecosystems in terms of collaboration and co-creation of values	Innovation	Implementation of innovation leads to commercial outcomes	Outcomes of innovation can be both commercial and non-commercial (i.e., 'soft' innovation)
	Networks	Business-oriented	Business- and community-oriented
	Boundaries	Geographic, industrial or sectorial	Local, national, transnational or global
	Collaboration	For value creation focusing on the frequency of interaction	The co-creation of values, which is 'an active, creative and social process, based on collaboration between producers and users, which is initiated by the firm to generate value for customers and compete to pass others in the category' (pp. 5246–5247); frequency of interaction and relationship quality are equally important
	Coordination	Innovation systems are pre-structured/coordinated through 'top-down intervention of any centralized bodies, or from an external intervention' (p. 5252)	Innovation ecosystems 'are able to self-organize and self-develop in a similar, agile manner of complex adaptive systems, associated with inter-relationship of elements, as well as with the ability to adapt in and evolve with a changing environment, with mutual respect' (p. 5252)

Table 2. Cont.

Studies and the Focus of Comparison	Dimensions for Comparison	Major Differences Identified	
		Innovation Systems	Innovation Ecosystems
Russell and Smorodinskaya [47]: comparing the ecosystem and system approaches to innovation and economic growth	Economic dynamics	Linear, closed, static and equilibrated systems	Nonlinear, open, dynamic and dissipative systems
	Emergence and synergy	‘Macro-level growth patterns are formed by linear summation of individual decisions of homogenous agents, with few synergies occurring spontaneously’ (p. 124)	‘Macro-level growth patterns emerge nonlinearly, out of synergies generated by dynamic network interactions of various heterogeneous agents at micro-level’ (p. 124)
	Network interactions	‘Network relationships are inessential, agents interact indirectly through market price mechanisms’ (p. 124)	‘Network relationships are essential, economic systems of all levels (from local to global) are seen as network-based ecosystems meant for innovation’ (p. 124)
	Predominant model of economic governance and adaptation	Hierarchic model: ‘The economy lacks feedback linkages for self-adjustment to [the] changing environment and, hence, has low capacity for adaptation’ (p. 124)	Heterarchical model: ‘The economy gets self-adaptable through interactive communication of agents, their feedbacks, their learning and proactive reciprocity’ (p. 124)
	Innovation	‘Limited endogenous capacity of economic system, dependent on a complex of its available resources’ (p. 124)	‘Sustainable endogenous capacity of economic system, based on internal incentives and new sources, arising from a system’s ability for continual self-correcting structural changes’ (p. 124).
	Innovation production model	‘Linear models of innovation (“technology push” and “demand pull”), driven by technological developments of individual firms’ (p. 124)	‘Interactive model: co-creation of innovations by networked agents through their collaboration within a generated ecosystem of linkages and assets’ (p. 124)

Table 2. Cont.

Studies and the Focus of Comparison	Dimensions for Comparison	Major Differences Identified	
		Innovation Systems	Innovation Ecosystems
	Institutional and business environment for innovation	'Creation of new institutions, technologies and industries is [a] higher priority than enhancement of cohesive context for a smooth dissemination of innovations across sectors and regions' (p. 124)	'Priority is given to continual improvements in environment, with the purpose to eliminate barriers and provide incentives for more business networks, more collaboration, more cohesion, and continual knowledge spillovers across and around the economy' (p. 124)
	Focus of strategies for innovation and growth	'To develop R&D and national innovation system by supporting its agents and infrastructure elements, with no focus on collaboration and its innovation synergy effects' (p. 124)	'To promote localized ecosystems across the economy and enhance their innovation synergy effects by facilitating the dynamics of interactions and collaboration within [and] between networks' (p. 124)

While these studies provide useful insights into the differences between innovation systems and innovation ecosystems, they do not collectively offer a consensus on what comparative framework should be used. Since the concept of innovation ecosystems evolved from the concept of an innovation system, we could use the main components of innovation systems as a lens through which to further identify new features of innovation ecosystems. When theorising about innovation systems, Edquist [31] suggested emphasising the nature of knowledge production, perceptions of innovation, key actors in the system, relations between the actors, and system boundaries and contexts. We used these dimensions to identify the unique characteristics of innovation ecosystems, and in doing so, we also synthesised the studies that conceptualised innovation ecosystems (e.g., [46,48]) and reviewed studies on innovation ecosystems (e.g., [4]). Table 3 presents the outcomes of the literature synthesis.

Table 3. Comparison of innovation systems and innovation ecosystems using Edquist’s lens. Source: authors’ synthesis of the literature.

Dimensions for Comparison	Innovation Systems	Innovation Ecosystems (Unique Features)
Nature of knowledge production	Transition from mode 1 (discipline-based) to mode 2 (practical and interdisciplinary) [49].	<p>Mode 3 knowledge production extends modes 1 and 2 and is defined as follows:</p> <p>‘The nexus or hub of the emerging twenty-first century Innovation Ecosystem, where people, culture and technology . . . meet and interact to catalyse creativity, trigger invention, and accelerate innovation across scientific and technological disciplines, public and private sectors . . . and in a top-down, policy-driven as well as bottom-up, entrepreneurship empowered fashion’ (p. 4) [50].</p>
Perception of innovation	<p>Technology innovation, defined as ‘something new that reduces operating costs and provides an improved product, service, or instrument that better meets the expectations of market participants’ (p. 2) [51], is the focus of innovation systems. Regarding studies on innovation systems, although there are a variety of definitions of innovation, ‘all authors working within the systems of innovation approach are centrally focused on technological innovation and, in addition, all are interested in organisational and institutional change’ (p. 10) [52].</p>	<p>In innovation ecosystems, both technological innovation and social innovation are important, and innovation must be sustainable [15,53], with an ultimate goal of a higher quality of citizens’ lives [54]. Sustainable innovation is defined as ‘innovation that improves sustainability performance, where such performance includes ecological, economic, and social criteria’ (p. 2) [55]. Social innovation is defined as ‘new ideas (products, services, and models) that simultaneously meet social needs (more effectively than alternatives) and create new social relationships or collaborations’ [56].</p>
Key actors and their functions	<p>Major participants and stakeholders in the research and development (R&D) systems.</p> <p>According to the Triple Helix model, which emerged in the transition from the political to the knowledge economy [57], universities, industries and governments are the main actors in innovation systems, in addition to some secondary actors, such as intermediaries, legal firms and non-governmental organisations [58].</p>	<p>In addition to traditional innovation actors, citizens are emerging as key actors [59].</p> <p>Interdependent actors combine specialised yet complementary resources or capabilities when seeking to co-create and deliver an overarching value proposition to end-users and appropriate the gains received in the process [60].</p> <p>The adaptive ability of innovation actors is becoming increasingly important [61,62].</p>
Relations between actors	<p>Reciprocal relations for value creation.</p> <p>The reciprocal relationship between primary innovation actors is the impetus of the Triple Helix model of innovation [63] that drives the development of innovation systems.</p>	<p>From value creation to co-evolution/co-creation [15,16] or co-innovation involving ‘collaboration, coordination, co-creation, convergence, and complementary’ [64].</p> <p>Actors are more interdependent and indirect relations are becoming more important [46,60].</p> <p>From innovation networks to complex innovation spaces: networks of networks [47,65].</p>

Table 3. Cont.

Dimensions for Comparison	Innovation Systems	Innovation Ecosystems (Unique Features)
System boundary	<p>National, regional and sectoral.</p> <p>The boundaries of innovation systems are often identified spatially or according to their sector [31].</p>	<p>Across regional and national boundaries [14,26,66]. Knowledge flows and innovation processes take place in multiple geographical locations or a global context [48,66]. Although the policies for developing innovation ecosystems are often made by region-based policymakers, a system's boundary does not depend on the region's geographical boundaries.</p>
System context	<p>Knowledge economy.</p> <p>'The concept of knowledge economy has developed as a rather vague persuasive notion concerning the relationships between advanced research and education on one hand and economic prosperity on the other' (p. 8) [67].</p>	<p>Knowledge society and the natural environment [48,68].</p> <p>The knowledge society, combined with the industrial economy and mass democracy, is not only a logical successor of the knowledge economy [67] but also something that co-exists with it due to 'the importance of techno-science for economic development' (p. 479) [69].</p>

3.2. Characteristics of the Neo-Triple Helix Model of Innovation Ecosystems

We continued to use the neo-Triple Helix model of innovation ecosystems proposed by Cai [30] to identify the characteristics of innovation ecosystems, which helped to concretise the concept of policy layering when attempting to understand what new policy arrangements for fostering innovation ecosystems should be layered on top of pre-existing structures of innovation systems, which were elaborated on by Cai et al. [23]. While Cai et al.'s [23] framework largely drew insights from the Triple Helix model of innovation (where interactions of universities, industries and governments foster innovation and entrepreneurship [20,70]), the neo-Triple Helix model of innovation ecosystems conceptualises what new elements are added on the Triple Helix model. By integrating the Triple Helix [71], Quadruple Helix [59] and Quintuple Helix [72] innovation models, Cai [30] proposed the neo-Triple Helix model of innovation ecosystems, which distinguishes two layers of triple helices: (1) university–industry–government triple helix interactions (i.e., ‘innovation genes’) and (2) triple helix interactions between innovation genes, social structures and the natural environment. The two kinds of helices generate innovation dynamics and sustainable development dynamics, respectively. Whereas an innovation system is mainly driven by innovation dynamics, an innovation ecosystem requires both innovation dynamics and sustainable development dynamics. The relevance of the neo-Triple Helix model to policy layering is illustrated in Table 4.

Table 4. Policy layering from the perspective of the neo-Triple Helix model of innovation ecosystems.

Layers of Helices	Layers of Dynamics	Layers of Characteristics	Layers of Policies
The first layer of triple helices	Innovation dynamics	Characteristics of innovation systems	Cai et al.'s [23] framework
The second layer of triple helices	Sustainable development dynamics	Unique characteristics of innovation ecosystems	A framework developed in the present study (presented in Section 4)

From the perspective of the neo-Triple Helix model of innovation ecosystems, the innovation dynamics of university–industry–government interactions are explained by the Triple Helix model, and the interactions between innovation genes, social structures and the environment that generate sustainable development dynamics in innovation ecosystems are explained by the Quadruple and Quintuple Helix models. Carayannis and Campbell [73] considered the core theses of the Quadruple and Quintuple Helix innovation systems as follows: first, democracy or knowledge democracy enables the advancement of knowledge and innovation; second, environmental challenges drive sustainable knowledge production and innovation.

Thus, when identifying what is new in innovation ecosystems, one should pay attention to the characteristics of innovation genes, social structures and the environment in the second layer of triple helices and the relationships between these components. Since Cai's [30] conceptualisation of these components is at a relatively abstract level, we aimed to concretise the three helices and their interactions based on the new features of innovation ecosystems discussed above. The unique features of innovation ecosystems from the neo-Triple Helix model's perspective are presented in Table 5.

Table 5. Unique characteristics of innovation ecosystems from the perspective of the neo-Triple Helix model. Source: authors' synthesis of the literature.

Dimensions	Main Characteristics
Innovation genes (innovation dynamics)	<ul style="list-style-type: none"> Generated innovations are sustainable or socially responsible. Both technological innovation and social innovation are fostered. Participants in a place-based innovation gene, with its enhanced adaptive ability, are increasingly interconnected with their counterparts in other innovation genes. Actors in collaborations or interactions develop co-innovation networks in which indirect relations between actors become increasingly important [2,46,48,53,61,62,66].
Social structure	<ul style="list-style-type: none"> Social structures are being transformed in the shift from a knowledge economy to a knowledge society or from industry 4.0 to industry 5.0 [5]. Sustainable innovation is fostered by a knowledge society or knowledge democracy in which there is a strong civil society that is characterised by a media- and culture-based public. 'On the one hand, public reality is being constructed and communicated by the media and media system. On the other hand, the public is also influenced by culture and values' (pp. 218–219) [59].
Natural environment	<ul style="list-style-type: none"> Sustainable innovation must be framed in the context of both civil society and the natural environment. Due to growing environmental concerns, actors participating in innovation processes tend to take on global responsibilities through cross-border collaborations. Sustainable innovation helps to avoid or resolve environmental challenges [53,72].
Co-evolution/co-creation relations between innovation genes, social structures and the environment	<ul style="list-style-type: none"> Innovation genes, social structure and the environment influence one another in the processes of value co-creation [15,74] and co-evolution [59]. In co-evolutionary processes, key actors in innovation ecosystems need to constantly adjust to adapt to environmental changes and create value [26].

4. The Role of Policy in Transforming Innovation Systems into Innovation Ecosystems

In this section, we discuss key factors to consider when designing policies that are intended to facilitate the transition from innovation systems to innovation ecosystems through theory adaptation. Specifically, we expand Cai et al.'s [23] framework for analysing the role of policy in this context.

4.1. Revisiting Cai et al.'s Framework: Innovation Policies and Their Roles in Developing Innovation Systems

In studies that examined the role of policies in innovation systems, such policies are often called innovation policies. They evolve out of science and technology policy regulations and address the development of innovation systems. By synthesising some classic innovation system literature [75–79], Cai et al. [23] found that 'innovation systems consist of complex functions and interactions among various organisations, including government, enterprises, universities and research institutes, as well as institutions, for example, policies and social norms, with the ultimate goal of boosting technological innovation and hence enhancing economic competitiveness' (p. 238). They further defined innovation policies 'as those governmental policies and programmes, on various levels and in different fields, which could either intentionally or by coincidence enhance enabling conditions of the innovation systems' (p. 240) [23]. Such a definition reflects a systemic approach to innovation [17] and a 'policy-mix' perspective [22]. Whereas the former addresses system failure instead of market failure [80], the latter views innovation policy as a mix of complex variables consisting of many interrelated policy elements [22].

Cai et al. [23] reviewed four approaches to innovation systems that are relevant to understanding the role of innovation policy: policy learning [21], system failure [17,18],

policy mix [22] and the Triple Helix [19,20]. All these approaches imply certain (ideal-type) enabling conditions for innovation system development, but ideal enabling conditions may not always be consistent with local conditions, especially in non-Western contexts [81]. Condition gaps can explain system failures, and the purpose of policy interventions is to change the conditions in a region to fill those gaps. Compared with the others, the Triple Helix approach provides a more comprehensive view of the enabling conditions of Triple Helix interactions that constitute the core innovation dynamics of innovation systems [82,83]. Consequently, Cai et al. [23] identified five categories of contextual conditions that are essential for innovation system development (Table 6).

Table 6. Enabling conditions for innovation systems. Source: adapted from Cai et al. [23].

Categories of Enabling Conditions for Innovation Systems	Enablers from the Triple Helix Perspective
Performance and competence of organisational actors	<ul style="list-style-type: none"> • Competencies of universities in knowledge generation and diffusion, absorptive capacity and demand of industry for knowledge and technology • Institutional entrepreneurs
Legislative and supportive infrastructures	<ul style="list-style-type: none"> • Supportive infrastructures for knowledge and technology transfer and intellectual property protection
Political and social value systems	<ul style="list-style-type: none"> • Public participation in decision making
Knowledge management	<ul style="list-style-type: none"> • Consensus on knowledge as the key to economic growth • Process-oriented knowledge management in knowledge production
Market mechanisms	<ul style="list-style-type: none"> • Market-oriented culture and a sense of competition

When designing innovation policies, policymakers should consider which policy instruments are most effective for use during an intervention based on the enabling conditions for regional innovation. This also entails that there is no one-size-fits-all approach, as a policy or programme that works well in one region may not be applicable in another setting. Cai et al.'s [23] framework for analysing the role of policy in innovation systems mainly provides a lens that helps researchers and policymakers to know where to start the analysis and what key issues to examine. To make the framework more operational, they suggested some example questions be asked when applying it to design and evaluate regional innovation policies (Table 7).

Table 7. The analytical framework for understanding how innovation policies influence the enabling conditions for innovation dynamics in innovation systems. Source: adapted from Cai et al. [23].

Categories of Enabling Conditions for Innovation Dynamics in Innovation Ecosystems	Issues to be Considered in Policymaking or Policy Analysis		
Performance and competence of organisational actors	Identification of gaps for innovation system development: What are the initial local conditions when developing a regional innovation system?	Mix of innovation policy instruments: What are the major policy instruments for developing innovation systems?	Efficacy of policies in filling condition gaps: How can policy instruments influence local conditions to fill gaps?
Legislative and supportive infrastructures			
Political and social value systems			
Knowledge management			
Market mechanisms			

4.2. *The Influence of Transformative Innovation Policy on the Transition from Innovation Systems to Innovation Ecosystems*

To distinguish between policy in innovation systems and innovation ecosystems, we refer to the former as innovation system policy and the latter as transformative innovation policy. Diercks [84] defined ‘transformative innovation policy as an emerging policy paradigm that represents a reframing of the policy objectives, domains and rationales of innovation policy to address not only economic but also wider social and environmental issues’ (pp. 34–35). Research on transformative innovation policy studies has been closely related to strategies for developing innovation ecosystems [85].

According to Schot and Steinmueller [7], public policies, including innovation policies, ‘arise from understandings of past experience with actions, reflections on contemporary challenges and perceptions of future potentials for action’ (p. 1554), which form the policy frames that guide policy analyses and policy actions. They identified three frames of innovation policy: frame 1 (innovation for growth), frame 2 (national systems of innovation) and frame 3 (transformative change) [7]. The three frames are, respectively, associated with (1) science and technology policies that emerged after World War II; (2) innovation systems policies developed since the 1990s and focus on building innovation networks and clusters and enabling entrepreneurship; and (3) transformative innovation policies that promote socially responsible innovation and achieving the SDGs [7,86], which are prevalent in current policy discourses.

Although they developed through an evolutionary process, the three frames co-exist [7]. The co-existing nature of policy frames can be explained by the concept of policy layering, which is ‘used to explain how a policy keeps its core purpose by adding new layers in response to political pressure for more substantial changes’ (p. 598) [87] and has been increasingly applied in transformative innovation policy studies [44,86]. According to the policy-layering approach, a transformative innovation policy is formulated by adding a new layer of policy to the layer of innovation system policy to address new features that have arisen in innovation ecosystems.

To identify new elements to be added to the new policy layer to facilitate the transition from innovation systems to innovation ecosystems, we focused on the features of innovation genes, social structures and the environment, as well as their interactions (Table 5), particularly their implications for the contextual conditions of the regions or nations in which policies are implemented to promote innovation ecosystems. As mentioned above, the interactions between innovation genes, social structures and the environment generate the sustainable development dynamics that represent what is unique about innovation ecosystems [30]. Thus, knowing what conditions enable sustainable development dynamics is essential. These conditions should be considered when designing transformative innovation policies in the new layer. In the following sections, we identify the conditions associated with the features of innovation genes, social structures, the environment and their interactions in the neo-Triple Helix model of innovation ecosystems.

4.2.1. *Enabling Conditions for Transforming Innovation Genes in Innovation Ecosystems*

The quality of innovation genes in innovation ecosystems is changing, which requires participants in the genes (e.g., universities, industries and governments) to operate in a complex context. On the one hand, actors in regional or national innovation ecosystems are interconnected with their counterparts in other innovation ecosystems, often on a global scale. On the other hand, the indirect or hidden relationships between innovation actors (especially those across geographical boundaries) are revealed and leveraged. For instance, in Cai et al.’s [46] study on transnational university–industry co-innovation networks (TUICNs) in innovation ecosystems, the authors emphasised the important role of hidden links between international university collaboration and international industry collaboration in building trust and fostering institutional change.

To enable the transformation of innovation genes, actors participating in innovation processes must have the vision and capabilities to build partnerships across geographical

and sectoral boundaries. In this regard, Cai [88] provided examples of the role of international university research collaboration in creating TUICNs. His study also suggested that policies and service providers should empower innovation actors committed to creating interlinks between regional or national innovation (eco)systems. Developing cross-boundary interactions on a global scale also requires innovation actors' adaptive capability, which is 'the ability to adapt to changing conditions' (p. 5) [62].

4.2.2. Enabling Conditions for Shaping Knowledge Democracy in Innovation Ecosystems

The social structures in innovation ecosystems are characterised by knowledge democracy. According to Carayannis and Campbell [73], to transform an innovation system into a Quadruple/Quintuple Helix innovation ecosystem, 'the political regime hosting these helixes needs to be democratic in essence, not just in form' (p. 1). While Triple-Helix-based innovation systems occur in the knowledge economy, Quadruple/Quintuple Helix innovation ecosystems emerge in knowledge societies or knowledge democracies [68]. The transition from a knowledge economy to a knowledge democracy (often referred to as a knowledge society) can be described as follows: 'As the industrial economy has been combined with mass democracy through universal suffrage and later by the rise of mass media, one might suggest that the logical successor of knowledge economy is a new type of governance, to be called "knowledge democracy"' (p. 6) [67]. Nevertheless, knowledge democracy recognises the co-existence of the knowledge economy due to 'the importance of techno-science for economic development' (p. 479) [69]. In a knowledge democracy, users are at the heart of the innovation processes, where 'users or citizens . . . own and drive the innovation processes' (p. 150) [48] and they increasingly interact with governments, businesses and educational institutions in innovation processes that are often associated with SDGs [54].

A fundamental condition for knowledge democracy is the 'bottom-up media' or 'new media' that supplements and competes with the 'top-down media' or 'classic media' [67]. The existence of bottom-up media means that 'citizens themselves have become media: any citizen may produce a YouTube picture that is world-famous in 2 days' (p. 5) [67]. According to in 't Veld [67], a knowledge democracy is shaped when the media joins the interactions between science and politics to form the knowledge democracy triangle. In the same vein, Carayannis and Campbell [50] argued that a knowledge democracy is enabled by 'media-based and culture-based public and civil society' (p. 13). Such a social structure facilitates grassroots entrepreneurship and public participation in innovation policy formulation, both of which are crucial in innovation ecosystems [14].

4.2.3. Enabling Conditions for Institutionalising Environmental Concerns in Innovation Processes

To fully address environmental sustainability in innovation ecosystems, there must be public awareness of environmental challenges and a strong sense of global responsibility within the social and organisational culture. The importance of the natural environment in innovation ecosystems was well elaborated in the Quintuple Helix model [72]. As noted by Carayannis et al. [68], 'the Quintuple Helix regards environmental or ecological challenges also as possible drivers for further and new knowledge and innovation, by this future knowledge and future innovation, which may have the potential to also finally advance society, economy and democracy' (p. 8). Therefore, innovations in innovation ecosystems are eco-innovations, also referred to as green innovation or sustainable innovation, which include 'not only environmental technologies but also processes, practices, systems, and services that improve the quality of human life while reducing the negative impact on the environment' (p. 2) [89].

To ensure that such environmental initiatives are fully considered in the process of knowledge generation and (social and technological) innovation, a sustainability ethos should be instilled among research organisations, firms and citizens that participate in innovation processes [90]. A sustainability ethos is in line with the norm of responsible

research and innovation (RRI), ‘a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to the (ethical) acceptability, sustainability, and societal desirability of the innovation process and its marketable products’ (p. 9) [91]. Studies showed that innovation participants from universities, industries and the public sector who are more inclined to RRI are more likely to contribute to sustainable innovation (e.g., [92,93]). When implementing RRI, companies not only innovate but also reflect the ethics underpinning their innovations [94]. In their case study of Quadruple Helix innovation in the energy sector in the Tampere region, Mehari et al. [93] found that although their interviewees, who were from different sectors, were unaware of the policy concept of RRI, they believed in the ideas underlying it, such as democracy, mode 3 knowledge production and (crossing-boundary) interdependency. Moreover, RRI entails an ecological dimension of sustainability [95].

4.2.4. Enabling Conditions for Co-Evolution/Co-Creation Relations between Innovation Genes, Social Structures and the Environment

When it comes to the co-evolution/co-creation relationship between innovation genes, social structures and the environment, it is important to know what value is co-created and what the selection mechanisms are in co-evolution processes. The literature on innovation ecosystems frequently refers to co-evolution and value co-creation as though there is a shared understanding of the terms. However, they are not clearly defined. The neo-Triple Helix model of innovation ecosystems implies that the relationships between innovation genes, social structures and the environment can be understood from a value system perspective; that is, the three components co-create value systems in a co-evolutional process. These value systems are (1) an environmental sustainability ethos enhanced by social actions responding to environmental challenges, (2) a social sustainability ethos developed in a knowledge democracy and (3) an economic sustainability ethos underlying the transformation of innovation genes in innovation ecosystems [30].

Deblonde [95] described the environmental, social and economic aspects of the sustainability ethos as the ‘strong’ version of sustainable development, equality and ‘a-growth’, respectively. In contrast to the ‘weak’ version of sustainable development, which assumes ‘that the degree of substitutability between . . . manmade and natural capital will always suffice to realise required utility’, the ‘strong’ version ‘assumes that possibilities to substitute are limited and that transgression of some absolute limits of natural capital poses a threat to the sustainability of societies’ (p. 25) [95]. Equality is considered a normative anchor point for sustainable development because ‘inequality—in both income and power—does not only result in unequal access to ecosystem services, but also in unequal distribution of the costs of environmental degradation’ (p. 25) [95]. A-growth is understood ‘in the sense in which we speak of “a-theism”, rather than “de-growth”’ (p. 8) [96]. This means that ‘being indifferent about growth is a more logical social aim to substitute for the current goal of economic growth, given that GDP (per capita) is a very imperfect indicator of social welfare’ (p. 881) [97].

Triple helix co-evolutionary processes are driven by selection mechanisms. While Leydesdorff [98] identified three selection mechanisms—namely, wealth creation, knowledge production and normative control in the Triple Helix model for innovation and economic growth—the selection mechanisms in the innovation genes–social structures–environment triple helix are (1) innovation for economic growth (associated with innovation genes), (2) public participation via democracy (related to social structures) and (3) the survival of humanity and higher quality of life for citizens (associated with the environment) (Figure 1). These mechanisms also reflect the ‘triple bottom lines of sustainability’: sustainability’s environmental, social and economic dimensions [99].

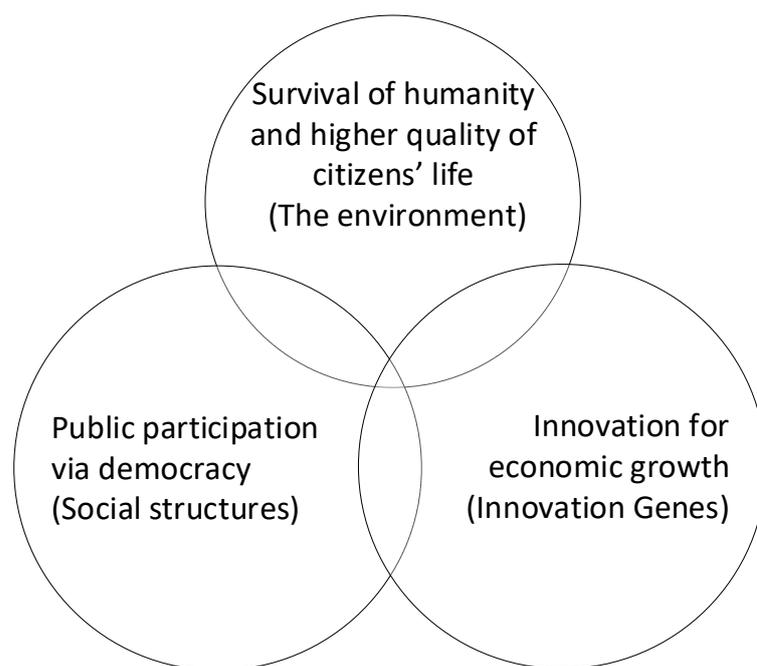


Figure 1. Selection mechanisms in the innovation genes–social structures–environment triple helix co-evolution process.

4.3. The Role of Policy in Changing Conditions That Enable Innovation Ecosystems

This section discusses the role of policy in influencing enabling conditions for innovation ecosystems. The enabling conditions for transforming innovation genes; shaping social structures; institutionalising environmental concerns; and the co-evolution relations between innovation genes, social structures and the environment are summarised in Table 8. The table also includes the expected major outcomes when the conditions are met.

Table 8. Conditions that enable the transition towards the neo-Triple Helix model of innovation ecosystems.

Key Aspects of Neo-Triple Helix Innovation Ecosystems	Enabling Conditions	Expected Outcomes when Conditions are Met
Innovation genes	Willingness and capacity of innovation actors (universities, industries and governments) to develop cross-boundary interactions on a global scale	Transnational co-innovation networks
Social structure	Civil society based on bottom-up media	Knowledge democracy
Environment	Prevailing sustainability ethos in economic, social and environmental dimensions: strong version of sustainable development, equality and a-growth	Environmental protection
Co-evolution/co-creation relationships between innovation genes, social structures and the environment		Sustainable development dynamics; integration of economic, social and environmental dimensions of sustainability

Next, we show how these conditions are described in studies that investigated relations between policies and innovation ecosystems (Table 9) to confirm the relevance of these conditions in policy design. It should be noted that although some studies refer to innovation ecosystems, they mainly touch upon the conditions required for innovation systems, similar to those mentioned by Cai et al. [23]. In our analysis, we focused on the unique conditions required for innovation ecosystems discussed in the literature.

Table 9. Enabling conditions for innovation ecosystems described in studies that investigated relations between policies and innovation ecosystems.

Conditions Enabling Innovation Ecosystems	Descriptions of Relations between Policies and Innovation Ecosystems in the Literature
Willingness and capacity of innovation actors to develop cross-boundary interactions on a global scale	In innovation ecosystems, cross-sector organisations need to collaborate at an unprecedented scale to uptake innovations, where such activities require intersectional investments [6,100]. Innovation actors and stakeholders in different regions are connected [33]. ‘The transformation of collocated facilities and expertise into dynamic innovation clusters requires that multiple individual actors recognize the opportunities and synergies that can arise from cooperation, diagnose prevailing collective action problems, and craft the rules needed to solve the myriad challenges to working together’ (p. 115) [32].
Civil society based on bottom-up media	While bottom-up entrepreneurial activities are as important as top-down policies in innovation ecosystems, fostering the former requires policies that support a bottom-up social structure [9]. The involvement of citizens and civil society organisations in setting research agendas and allocating public research funds is an essential aspect of transformative policies [37].
Strong version of sustainable development	‘The shift from linear production and consumption systems to circular and slow material loops decoupling environmental impact from economic growth’ (p. 16) [38].
Equality	How inequality issues are addressed in policies for inclusive innovation development is detrimental to shaping innovation ecosystems [34]. ‘Designing inclusive processes is a crucial precondition for evidence-informed learning and decision-making’ (p. 246) [36] for achieving the SDGs.
A-growth	Instead of seeing GDP growth as a precondition for well-being, Hirvilammi [35] proposed the virtuous circle of a sustainable welfare model in which ecological sustainability is the primary precondition for all policies.

The enabling conditions discussed above can be treated as factors to be considered in transformative innovation policymaking, adding a new layer to existing innovation system policies. We further allocated the new layer of conditions (Table 9) into the dimensions in Cai et al.’s [23] framework concerning enabling conditions for innovation systems, resulting in Table 10. It should be mentioned that both the conditions required for innovation systems described by Cai et al. [23] and those required for innovation ecosystems proposed in the present study are ideal types. Although policymakers or innovation organisers often try to achieve ideal-type conditions, there are always gaps between realities and ideal situations. As noted by Streeck and Thelen [101], ‘the enactment of a social rule is never perfect and that there always is a gap between the ideal pattern of a rule and the real pattern of life under it’ (p. 14).

Since the role of policy for developing innovation (eco)systems is to foster ideal-type conditions, these conditions are important factors in policymaking. This means that the purpose of a policy is not to directly influence actors’ behaviours but to create an optimal environment in which relevant actors can independently develop strategies to maximise their performance. Such a perspective is in line with ‘design policy’, which aims to create an environment in which actors in each relevant sector can better perform and be creative by designing their strategies [102]. Design policy should not be a rational and straightforward problem-solving activity but ‘a socially based, collective activity for generating solutions to complex problems and challenges’ (p. 278) [103]. From a design perspective, policymakers need to have the ability to make complex things (in innovation ecosystems) simple and make more simplified information richer and more manageable for communications in policymaking processes [104]. Design policy or design-driven approaches to innovation have frequently been used by the EU and EU member states (e.g., [105]).

Table 10. Enabling conditions to be addressed in a new policy layer for transforming innovation systems into innovation ecosystems.

Dimensions of Enabling Conditions	Conditions Enabling Sustainable Development Dynamics in Innovation Ecosystems (Factors to Be Considered when Adding a New Policy Layer)
Performance and competency of organisational actors	Willingness and capacity of innovation actors (universities, industries and governments) to develop cross-boundary interactions on a global scale
Legislative and supportive infrastructures	Civil society based on bottom-up media
Dimensions in Cai et al. [23]	Prevailing sustainability ethos in economic, social and environmental dimensions (strong version of sustainable development, equality and a-growth)
Political and social value systems	N/A (The conditions in this dimension mainly matter to innovation dynamics in innovation ecosystems and do not concern sustainable development dynamics in innovation ecosystems.)
Knowledge management and market mechanisms	N/A (The conditions in this dimension mainly matter to innovation dynamics in innovation ecosystems and do not concern sustainable development dynamics in innovation ecosystems.)

When designing transformative innovation policies to influence the transition from innovation systems to innovation ecosystems, policymakers can examine the conditions listed in Table 10 and ask the following questions suggested by Cai et al. [23]: (1) What are the possible gaps between the conditions in reality and the ideal-type conditions? (2) What policy instruments can be used to bridge these gaps? (3) How can the effectiveness of policy instruments be evaluated? Following the policy-layering approach, there is no need to abandon existing innovation policies. Instead, the new policy layer can be designed and implemented by initiating new programmes and actions; ‘policy making is the process by which governments translate their political vision into programmes and actions to deliver “outcomes”’ (p. 15) [106]. For instance, the EU has launched dozens of programmes and budgets supporting the development of innovation ecosystems in Europe [42], such as:

- The European Regional Development Fund (ERDF), which focuses on building infrastructure for research and innovation ecosystems, the modernisation of public and private sectors, and cooperation networks and clusters
- The Programme for Environment and Climate Action (LIFE), which facilitates the shift towards a sustainable, circular, energy-efficient, renewable energy-based, climate-neutral and resilient economy; protects (restores and improves) the quality of the environment; and tackles the degradation of ecosystems.

While addressing new enabling conditions, transformative innovation policies also entail a different expectation of institution–action interactions than that of innovation policy. From an institutional theory perspective, public policies primarily deal with institutional structures and the actions of organisations or individuals [107]. Beaudry et al. [6] aptly noted the differences between innovation systems and innovation ecosystems from an institution–action perspective:

A system of innovation focuses on how the nature of interactions between existing institutions (which remain unchanged in the process) conditions innovation trajectories (‘how institutions drive action’). . . . The notion of ecosystem does not assume that institutions already exist. Instead, it concentrates on the dynamics of innovation that lead to the transformation of institutions or the formation of new institutions and practices (‘how action drives institutions’) (p. 536) [6].

Indeed, the evolution from innovation systems to innovation ecosystems are institutional changes that reinforce a sustainability ethos. For instance, one of the significant changes is described by Deblonde [95] as follows: ‘economic ambition of “maximising utility of natural capital” should be replaced by a (practical) societal ambition of “preserving resilience of life support systems”’ (p. 15). Drawing on Beck’s [108] concept of

‘paradigm confusion’, which describes contradictions between economic goals and socio-environmental needs, Saravanamuthu [109] noted a normative change that follows the introduction of a sustainability ethos—from the ‘zero-sum presumption that supports economic growth at the expense of the natural environment’ to the concern that ‘the real-world environmental devastation wrecked by unfettered economic growth’ (p. 10).

5. Conclusions

Based on the unique features that distinguish innovation ecosystems from innovation systems identified in this study, we suggested three ideal-type conditions that are required to create innovation ecosystems: (1) the willingness and capacity of innovation actors to develop cross-boundary interactions on a global scale; (2) civil society based on bottom-up media; and (3) a prevailing sustainability ethos, including a strong version of sustainable development (environmental dimension), equality (social dimension) and a-growth (economic dimension). The role of policy in the transition from innovation systems to innovation ecosystems lies in its ability to move the local context towards the ideal-type conditions. The underlying assumption is that when optimal contextual conditions are set, actors in innovation ecosystems can perform better by creatively designing their strategies. Since making policies that foster the creation of innovation ecosystems is becoming increasingly complex [47], the approach proposed in this study helps policymakers grasp the essential factors, thus making policy design more feasible. The framework developed in this study can also guide policy evaluation regarding the efficacy of policy in developing innovation ecosystems. Nevertheless, the framework must be tested and improved through policy analysis and policy planning in various empirical contexts.

Our research contributes to the literature in three ways. First, by bringing studies comparing innovation systems and innovation ecosystems under a consistent comparative lens, we identified the unique characteristics of innovation ecosystems. This lens helps to synergise the various studies conceptualising innovation ecosystems. Second, by elucidating what is unique about innovation ecosystems, we developed a framework for analysing the role of policy in transforming innovation systems into innovation ecosystems. The framework distinguishes between enablers of innovation dynamics underlying innovation systems and enablers of sustainable development dynamics that are unique to innovation ecosystems from the perspective of the neo-Triple Helix model [30]. Third, while applying the concepts of policy layering and transformative innovation policy in our analytical framework building, we advanced studies on the two concepts by conceptualising transformative innovation policy as new policy arrangements layering on top of pre-existing innovation system policies.

The limitations of this study concerning its relatively narrow focus indicate some potential avenues for further research. First, although this study focused on identifying new conditions that enable transitions from innovation systems to innovation ecosystems, policymakers should also pay attention to such conditions from a ‘path-dependency’ [110] perspective. In light of historical institutionalism, ‘path dependency not only connects the past to the present but also highlights the fact that the past limits the range of choices in the present’ (p. 570) [111]. Its implication for policy analysis is that ‘policy change at one point in time created institutions which served as a barrier to change at a later point’ (p. 73) [107]. Thus, future research should investigate how previous policies for optimising conditions that enable innovation systems might become institutional constraints for institutional changes underlying innovation ecosystem development.

Second, for policymakers, being aware of the conditions that foster the transition from innovation systems to innovation ecosystems is necessary but not sufficient. Since the ultimate goal of transformative innovation policy is institutional change, policymakers should also identify potential change agents in the process and empower them through appropriate policy instruments. Thus, in future research, the framework for the role of policy in influencing enabling conditions for innovation ecosystems should incorporate

the insights of recent studies on change agents and their roles in changing the institutional contexts for sustainable innovation and green growth [112,113].

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